$1\frac{1}{4}$ inch in diameter to represent the Moon, from the centre of which concentric circles and straight lines at angles of 30 degrees are drawn, as in the accompanying diagram, to place correctly the outlying portions of the corona in position and to scale. A weight must be suspended by a string in such a position that the observer can see it hanging over the Sun's centre, and the diagram upon which the drawing is to be made so placed upon a convenient stand that the line marked "top," "bottom" shall be in the plane passing through the observer's eye, the string, and the Sun's centre; the end marked "top" of the diagram must correspond to the top of the string.

It may be desirable that two or three minutes before totality the observer should cover his eyes, to render them sensible to feeble light, leaving it to a friend to warn him when totality begins; but this should not be carried far enough to strain the eyes.

On the Equipment of the Astrophysical Observatory of the Future. With two Appendices: Appendix I.—On the Support of Large Specula; Appendix II.—On Making the Siderostat an Instrument of Precision. By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

Hitherto the scrutiny of separate celestial objects, or of fields of view, whether by eye observations, with the photographic camera or through the spectroscope, has been carried on amidst practical difficulties with equatorial telescopes expensively mounted and under cumbrous movable domes. To the eye end of the telescope the camera, spectroscope, or other apparatus has had to be attached under conditions not easy to secure, and the apparatus can only be of such a kind as the telescope is able to carry, and which may with safety be borne by the equatorial movement into positions which are often inconvenient and always changing. These limitations preclude the use of delicate apparatus, such as micro-radiometers, which can only be set up upon a fixed support, or of complex appliances, such as the apparatus for producing monochromatic images, recently described by Captain Abney, and from the employment of which, or of other apparatus of a like kind, we may reasonably look for a great accession to our knowledge of the physics of the Sun.

However, the extraordinary success with which instrument makers can now figure large flat mirrors, the much greater facility and certainty with which they can be resilvered, and the possibility of supporting them in all positions with the requisite delicacy and without risk of shifting their line of collimation, by the arrangement described below in Appendix I., give an opportunity of remedying all this. We have it thus within our power

to equip an equally efficient and much more convenient astrophysical observatory at a less cost than hitherto, or by an equal expenditure to furnish one which can accomplish much more.

There are four ways in which the flat speculum may be employed : in the ordinary siderostat, described early in the eighteenth century by s'Gravesande ; in the polar siderostat ; in the modification of the polar siderostat, suggested some years ago by Sir Howard Grubb, in which the objective is outside the flat mirror, and is, along with it, carried round by the polar axis ; or, finally, in that very meritorious instrument the cœlostat, an instrument of which the polar axis is driven round once in forty-eight hours. An instrument driven in this way was constructed and described by Mr. Conrad Cooke many years ago, but its real value was not known till it was pointed out by M. Lippmann last year, that the image furnished by it does not rotate in the field of view if the mirror be placed strictly parallel to the polar axis. All of these have their special advantages and disadvantages, and it is probable that a fully-equipped astrophysical observatory should possess more than one of them.

For photographic work the polar siderostat, whether in the usual or in Sir Howard Grubb's form, and the cœlostat, offer the greatest advantages in dealing with all parts of the sky, except a small region in the immediate neighbourhood of the pole, for which special provision, not difficult to contrive, would have to be made.

With the polar siderostat the telescope must be placed in or parallel to the polar axis. The telescope may be either stationary in the axial position or carried round by the axis, but, in any case, the camera must be attached to the moving axis and rotate with it, in order that the image may remain in one fixed position upon the photographic plates. A spectroscope when used with a polar siderostat may be set up in one fixed position whenever, as is usual, the rotation of the image in the field of view is immaterial.

Astronomers have a well-founded distrust of convertible instruments ; but the structural provision which would have to be made in order to convert a polar siderostat into a cœlostat is of such an extremely simple and unobjectionable kind that it is probable that the same instrument could safely be made to serve in both capacities. When used as a cœlostat, the telescope with its camera, or other apparatus, is to be mounted on a nearly horizontal table, which can traverse round in azimuth, and slope upwards and downwards through a few degrees. There are many kinds of bulky or delicate apparatus which would admit of these motions, although they could not be carried into the positions into which an equatorial would sweep them ; so that the range of work which can be done in the observatory will be increased.

When, however, we want to use the most powerful spectroscopes, such as Rowland's largest concave gratings, or very deli-

cate instruments, such as Professor Boys's radio-micrometer, the ordinary siderostat, s'Gravesande's siderostat, if it can be perfected, offers immense advantages, since the telescope and associated apparatus can remain immovable in a horizontal position, while all requisite adjustments are made upon the siderostat. These are matters of great practical convenience. It is to be remembered that the only defect which the siderostat has, namely, that the image furnished by it slowly rotates in the field of view, is of no detriment for stellar spectroscopy. By employing a s'Gravesande's siderostat, therefore, we may bring much more powerful appliances than heretofore to bear on the spectroscopic examination of stars, and we shall use them under the most convenient conditions.

The only inferiority of this instrument to the polar siderostat as an instrument of precision lies in the sliding motion which has always hitherto been made use of in it. But a model which was exhibited at the meeting, and which is described in Appendix II., shows that this sliding motion may be got rid of, and a continuous motion substituted, with details that possess every quality which is essential for extreme astronomical precision. With this improvement the s'Gravesande siderostat becomes an instrument that can be relied on in the astronomical observatory, and will be found probably much the most useful form of siderostat for all work which is compatible with the image rotating in the field of view.

What I suggest accordingly is, that the astrophysical observatory of the future be furnished with a polar siderostat convertible into a cœlostat, and where practicable with an ordinary siderostat also, instead of with an equatorial; and that whatever is saved by the less expensive mountings and roofs, be employed in increasing the size and excellence of the mirrors and objectives. It is anticipated that in this way an astrophysical observatory may be constructed for carrying on the whole of the existing work with increased facility, and that it will besides bring within our reach important new branches of work, and extensions of the older work, which have hitherto been impracticable.

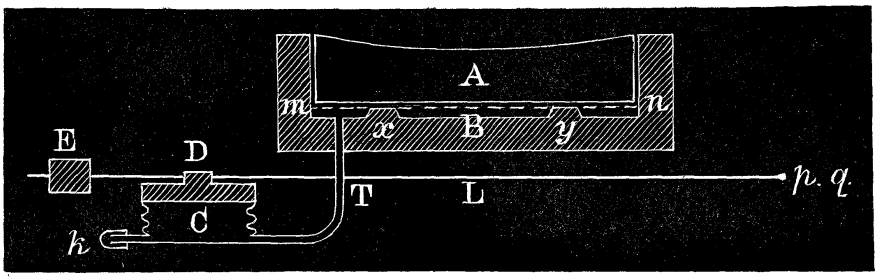
Appendix I.

On the Support of Large Specula.

The chief obstacle to the use of large specula in the astrophysical observatory, and especially for photographing the heavens, is that shifting of the line of collimation to which they are liable when the mirror is made to follow the motion of the celestial object.

The difficulty in preventing this shifting of the line of collimation arises out of the necessity for applying an extremely equable pressure over the back of the mirror which shall vary in amount according as changes in the altitude bring more or less

of the weight of the speculum to act upon its back support; and the necessity for avoiding the pinch to which changes of position or unequal expansion are apt to give rise. In the case of large specula the support is usually "a bed of levers," which, to act with the requisite delicacy, must somewhat yield; and when it yields, it is difficult—and with the largest mirrors practically impossible—to prevent some slight shifting of the plane of the mirror, which, of course, alters the line of collimation, and, for example, makes it impossible to take the best photographs with these great instruments, which otherwise would be the best for the purpose.



In the proposed arrangement the bed of levers is got rid of, and a pneumatic support takes its place. The mirror is mounted in a cell which takes the edgewise pressure, and in which it may be held without pinch and as nearly rigidly as an object-lens, if at the same time the back of the mirror receives such an equable pressure over its whole surface as shall exactly balance the normal component of its weight.

This is accomplished as follows. The cell is divided into two chambers, A and B, in the upper and larger of which the mirror is situated, resting on three props, x y z, of which two are shown in the figure, and which come into action only when there is insufficient air in the lower chamber.* An air-tight partition of thin flexible sheet-metal, represented in the figure by the dotted line m n, is to separate the lower from the upper chamber. This partition should be corrugated somewhat like the top of the vacuum chamber of an aneroid barometer, to provide for the difference in expansion between metal and glass. The lower chamber B may be very shallow—in fact, a mere chink. It communicates through the tube T with the regulator C, which is another air-chamber. In many cases this regulator may simply be a common air-cushion of appropriate size, in which the air is compressed by the disc D, which is forced against it by the lever

* Or, if it be found that there is risk of strain beyond the limit of elasticity when there is insufficient air, a bed of levers within the chamber B may take the place of the three props. When the proper amount of air is introduced it just relieves the pressure from the props or bed of levers, so that the latter only act while there is insufficient air.

L, at one end of which is the counterpoise E, and at the other end of which are the pivots p and q, one of which is above and the other under the plane of the section represented in the diagram. The whole of this apparatus is to be attached to the cell carrying the speculum, so as to accompany it in its motions. By this arrangement only one component of the weight of the counterpoise and lever acts on the regulator, the components which are parallel to the plane of the speculum being supported by the pivots p and q. In this way the air in the regulator, and consequently the air in the chamber under the mirror, is in all positions compressed in exactly the proper degree to support the normal component of the weight of the mirror. K is a nozzle through which air may be pumped in, if in the course of time there should be some leakage. The amount of the compression and the variations of pressure, even for so great and so heavy a mirror as either of Lord Rosse's two great six-foot mirrors, one of which weighs four tons and the other three tons and a half, are so slight that they would in no sensible degree interfere with the accuracy of the working of the arrangement; and with it the line of collimation can be kept as rigidly fixed in relation to the cell as any astronomical work requires. The mirror, of course, will need to have been ground and polished upon a similar support, as large mirrors do not admit of any alteration being made in their support without deformation.

In a small working model which was shown at the meeting of the Society, a large ordinary air-cushion took the place of the chamber B and the regulator C. It was in a chink between two boards, in the upper of which boards were two circular holes; the larger one to allow a twelve-inch speculum to rest upon the air-cushion, and the smaller one for a wooden disc pressed against the air-cushion by the counterpoise and lever. The boards prevented any expansion of the air-cushion, except where the mirror and counterpoise reached it.

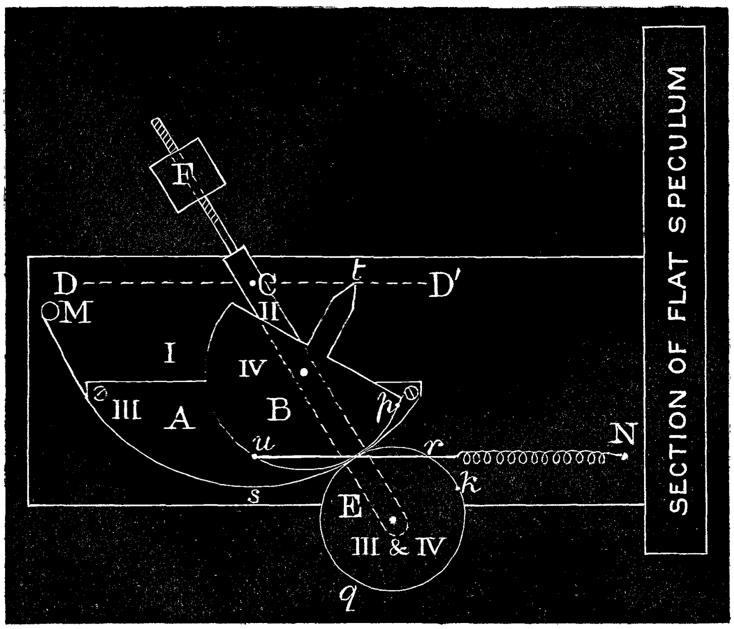
Appendix II.

On making the Siderostat an Instrument of Precision.

When the difficulties in the support of the flat mirror are fully got over (see Appendix I.), the chief obstacle to making the siderostat an instrument of astronomical precision lies in the necessity of providing a rectilinear motion between the mirror and that arm which the clockwork acting on a polar axis keeps pointed either directly towards or directly away from the celestial object, while the latter travels across the sky in its diurnal course. Hitherto this rectilinear motion has always been effected by a tube fitted upon the end of the arm sliding along a straight bar attached to the mirror, an arrangement which cannot always be relied on for extreme astronomical accuracy. Attempts have been made to substitute a continuous motion for this sliding

motion, but hitherto without getting over the practical difficulties. But the following arrangement appears to meet these difficulties so satisfactorily, that with it s'Gravesande's original pattern of siderostat, now commonly known as Foucault's, or that other type which the present writer adopted in the small "local heliostats" intended for use in physical laboratories, can either of them be made instruments of as great precision as the equatorial telescope.

In order to provide the rectilinear motion, use is made of the well-known kinematical principle, that if a circle roll on the inside of another circle of double its diameter, each point on the circumference of the smaller circle will traverse a diameter of the larger circle backwards and forwards. A working model was exhibited to show how this principle is to be applied, the essential



parts of which are represented in the accompanying diagram. M N is a sole-plate to which the apparatus is attached, and it lies at the lowest level in the diagram, which is indicated by the number I upon it. Next above it, indicated by the number II, is the lever E F, which turns on the pivot C standing up from the sole-plate. In the next tier, indicated by the number III, stands A, an arc of the larger circle, which is attached to the sole-plate, but propped up from it by two blocks at its ends, so as to leave space enough between for the lever E F to play. The pivot C is at the centre of this larger circle, and D D′ is one of its diameters. In the next tier, indicated by IV, is the small circle B of half the diameter of the larger. It turns on a pivot which stands up from the lever E F. Another pivot, standing up from

this lever, carries the idle drum E, which is rather more than twice as thick as A or B, so that the lower part of it is at the level of tier III and the upper part at the level of tier IV. Round the upper part passes a flexible steel band which is fastened at k, and from that goes in the direction $k\,q$ to p, where its other end is fastened to the wheel B. At the lower level another steel band is fastened at k, which passes in the direction $k\,r\,s$, round the larger wheel on to M, where it is fastened to the sole-plate by some contrivance which allows it to be a little lengthened or shortened at will. By this arrangement, if both bands are kept taut, the wheel B is made *to roll on the inside* of the wheel A. The steel bands are kept taut by the spring Nu, which is attached to the sole-plate at N, and to the wheel B at that point on its circumference which is opposite to the pointer t. This point u, like every other point on the circumference of the wheel B, traverses a portion of a diameter of the larger circle A, which in this case is a short part of the vertical diameter in the figure ; and if N is placed sideways at the height of the middle of this short part, the spring will scarcely lengthen or shorten during the motion, so that even if strong, it neither throws a sensible amount of energy into the moving system nor withdraws sensible energy from it during the motion : in other words, the spring may be strong enough to effectually prevent all back-lash, and will notwithstanding allow the movement of the apparatus to be sensibly smooth and unimpeded throughout its whole range, a matter of importance in an instrument to be driven by clockwork.

During the motion, t, which is also a point on the circumference of B, traverses one of the diameters of the larger circle A, and this can be made any desired diameter, D D′, by adjusting the length of the second steel band at M, where provision for making this adjustment can conveniently be made. In the Foucault type of siderostat it is, of course, to be adjusted so as to be perpendicular to the reflecting surface of the flat mirror.

The whole arrangement has, therefore, to be attached to the back of the cell carrying the flat mirror. If rigidly attached, a universal joint of some kind must be provided where the end of the arm carried by the polar axis is connected with the end of the pointer t, which is the point that is constrained to move in a straight line perpendicular to the mirror. If attached in this way, the planes of the wheels A and B continue vertical throughout the motion. Another mode of attachment is to mount the whole so as to swing on a straight bar attached perpendicularly to the back of the mirror, so that the axis of the bar shall occupy the position marked in the figure by D D′. In this case a ring, which shall pass round this bar without touching it, must take the place of the pointer t, and with this the arm of the polar axis may be more simply connected. If mounted in this way the new apparatus will shift part of the way round the bar during the motion. But whichever arrangement is adopted, one counterpoise F will balance the moving parts in all positions. It will probably be

found convenient to duplicate the lever E F, and place half or a certain portion of the counterpoise at the end of each duplication, so as to keep the counterpoise clear of the polar axis and its arm in every position.

On the Importance of Accurately Observing the Leonids this Year.

By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

The *Leonids*, the great November swarm of meteors, is the meteoric stream about which astronomers know most.

This great body of meteors traverses an immense oval orbit which, near its farther apse, crosses the path of the planet *Uranus*, and near its perihelion crosses the earth's path. The meteoric orbit does not intersect the orbits of the intermediate planets, *Saturn*, *Jupiter*, and *Mars*, owing to the considerable inclination of its plane. Round this great inclined orbit the meteors glide in a stream which lengthens as it moves inwards towards the Sun, and becomes shorter during each outward journey. Where the swarm passes the Earth it is about 100,000 miles thick, and of such a length that, though it travels at the rate of 27 miles a second, the great procession takes two years to pass us, and when its hinder part is still with us, its front will have reached to between the orbits of *Jupiter* and *Saturn*. Nevertheless, although so immensely long, it extends over only a portion of the circumference of its own great orbit, which it takes about a third of a century to traverse.

The front of this great swarm will next reach the Earth's orbit late in the spring of 1899. The Earth will then be in a distant part of its orbit, but in the middle of the following November and in November 1900 it will pass obliquely through the mighty stream, and on each of these occasions there will be an astounding rain of meteors, probably for about five hours, on the whole of the advancing side of the Earth.

Now, when we have regard to the fact that these meteors are not visible in outer space, and that we can only, and only for a second or two, observe that small proportion of them which happen to flash into some part of our small atmosphere, it is truly astonishing that it has been possible to gain so much knowledge of their movements and history.

Astronomers may be divided into two classes—chamber astronomers and observers. Sir Isaac Newton was the greatest of the former class, and the late Professor Couch Adams was one of the greatest of modern times. To him and to Professor H. A. Newton, of New Haven, we chiefly owe the great discovery. Before the visit of the meteors to the Earth in 1866 and 1867, Professor Newton pointed out how to deal with the problem, but it was by a process so difficult that it remained doubtful whether

M M